REAL-TIME BARCODE READER USING ACTIVE VISION

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Specially dedicated to my family for their support and eternal love.

"If you can dream it,
you can do it"

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ABSTRACT

Barcodes are commonly used with merchandise to speed up product checkout at department stores and to keep inventory. A barcode is a machine readable code consisting of a series of bars and spaces printed in defined ratios. The function of the barcode scanner is to “read” the image presented by the bar code. Common handheld scanning technologies include wands and lasers. They have some limitations such as limited depth of field, limited life span due to mechanical wear and the barcodes must reside on flat surfaces. Besides that, barcodes must be aligned in a proper way for reading thus limiting the robustness of these readers. This project is aimed towards improving these limitations, by using an active vision system. This project is to decode the UPC-A and EAN-13 barcodes using an active vision system, consisting of a camera and user-written software. The camera will feed the software with continuous frames of images from the environment. These images are converted to grayscale and some preprocessing is performed. Image is filtered (such as sharpening and noise reduction) and converted to binary. An adaptive thresholding algorithm is used to reduce the effects of uneven illumination. Image is then scanned horizontally, vertically and diagonally for barcodes, thus enabling it to decode rotated barcodes. Error correction and predictive decoding is implemented to improve the speed and accuracy of the system. Overall system performance is benchmarked with existing commercially available software.

ABSTRAK

Kod bar digunakan secara meluas dalam urusan pembelian di pasar raya dan juga digunakan untuk merekod inventori. Kod bar merupakan sejenis kod yang terdiri daripada lajur and ruang dalam nisbah tertentu, dan kod ini boleh di baca oleh mesin. Fungsi pembaca kod bar adalah untuk membaca imej kod bar yang terpapar. Antara teknologi pembaca yang lazimnya ditemui adalah berasaskan laser dan mempunyai beberapa kelemahan, seperti jarak pembacaan yang rendah, mudah mengalami kerosakan mekanikal dan hanya boleh membaca pada permukaan yang rata. Di samping itu, kod bar mestilah diaturkan dengan betul untuk tujuan pembacaan. Matlamat utama projek ini adalah untuk mengatasi masalah-masalah ini dengan menggunakan teknik penglihatan. Projek ini akan menguraikan kod-kod bar UPC-A dan EAN-13 mengunakan teknik penglihatan yang mana sistem ini terdiri daripada sebuah kamera dan aturcara. Kamera akan menghantar kerangka gambar secara terus-menerus kepada aturcara. Gambar akan ditukar kepada skala kelabu dan beberapa proses awalan akan dilakukan. Gambar akan ditapis untuk ditajamkan atau untuk menghilangkan hingar dan kemudiannya ditukar kepada gambar hitam-putih. Operasi ambang dengan penyesuaian sendiri digunakan untuk mengurangkan kesan pencahayaan tidak sekata. Gambar kemudiannya dibaca melintang, menegak dan menyerong supaya kod bar dalam pelbagai putaran dapat dibaca. Operasi pembetulan kesalahan dan ramalan dalam penguraian dilaksanakan untuk meningkatkan kelajuan dan ketepatan sistem. Prestasi keseluruhan sistem diuji dan dibandingkan dengan aturcara-aturcara komersial.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF NOTATIONS

a	Lens aperture (f-stop)
c	Diameter of circle of confusion.
d_i	Distance from the image plane to the optical center of the lens
d_o	Distance from the object plane to the optical center of the lens
f	Focal length
H	Hyperfocal distance
h_{ccd}	Height of CCD in pixels
h_i	Height of image in millimeters
h_o	Height of object in millimeters
T	Threshold value
T_g	Global threshold value
T_o	Threshold Convergence factor
w_{ccd}	Width of CCD in pixels
w_i	Width of image in millimeters
w_o	Width of the object in millimeters
θ_h	Vertical angle of view
θ_w	Horizontal angle of view

LIST OF ABREVIATIONS

AoV	Angle of View
BMP	Windows Bitmap
BPNN	Back Propagation Neural Network
CCD	Charge-Coupled Device
CMOS	Complementary Metal Oxide Semi-Conductor
CoC	Circle of Confusion
DoV	Depth of View
EAN	European Article Number
FF	Far-Field
FoV	Field of View
FPS	Frames per Second
ISBN	International Standard Book Number
LUT	Look-up Table
MLP	Multi Layer Perceptron
MMX	MultiMedia eXtension
NF	Near-Field
PCI	Peripheral Component Interface
PDA	Personal Digital Assistant
px	Pixel
RBF	Radial Basis Function
RGBA	Red-Green- Blue-Alpha
SIMD	Single Instruction Multiple Data
SSE	Streaming SIMD Extensions
UPC	Universal Product Code

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.1 Introduction

Barcodes are machine readable symbols made of patterns and bars. Barcodes are used for automatic identification and usually are used in conjunction with databases. It is widely used in the retail industry, military, health industry, document imaging environments, automatic storage and retrieval systems [1] and on the factory floor. Barcodes were first introduced about 34 years ago [2]. The main intention is to encode information in a tight place. It is also a very simple method of data entry and data collection and is used for supply monitoring, job control and batch separation [3]. Barcodes are very cost-effective, accurate and can pack great amount of information [2]. The cost of printing and reading is minimal [4] and moreover, the actual labor cost for data entry is reduced.

Different bar and space patterns are used to represent different characters. Sets of these patterns are grouped together to form a "symbology". There are numerous types of barcode symbologies each having their own unique characteristics and features. A majority of symbologies were designed to meet the needs of specific applications or industry. For example the Universal Product Code (UPC) symbology was designed for identifying retail and grocery items, while PostNET was designed to encode postcodes for the US Postal Service. Generally, barcodes can be categorized into two distinct categories;

a. One-Dimensional (1-D) barcodes

These barcodes encode information along one dimension with intervals of alternating black and white color. Information is encoded in bars which represents the barcode. The term bar refers to the rectangles with the foreground color while spaces denote the intervals between the bars. Example of 1-D barcodes are like the Codabar, Code 25, European Article Number (EAN-8, EAN-13), UPC-A and PharmaCODE which are shown in Figure 1.1. 1-D barcodes differ from one another by the way the information in encoded. Some symbologies allow encoding of both numeric and alphanumeric characters.

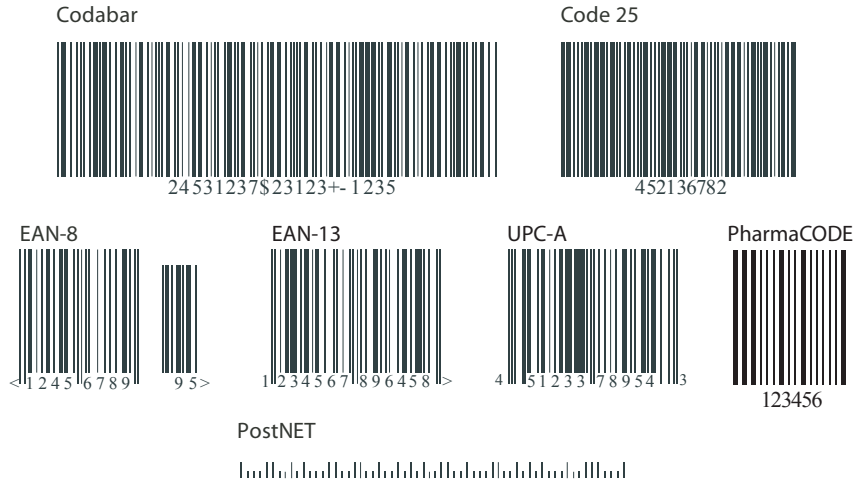

Figure 1.1: Common one-dimensional barcodes

b. Two-Dimensional (2-D) barcodes

2-D barcodes can represent more information per area and was developed to overcome the restricted amount of information that can be packed in 1-D barcodes [5, 6]. 2-D barcodes represent information in two axes, creating an area of barcode. Examples of 2-D barcodes are such as 3-DI, Array Tag [7, 8], PDF417 [6], Data Matrix, MaxiCode and Aztec Code and are shown in Figure 1.2. Besides that, 2-D barcodes are smaller and have a lower error rate compared to their 1-D counterpart. For instance, the PDF417 barcode has a worst case error rate of 1 error for 10.5M characters, compared to UPC-A which has a higher error rate of 1 error for every 394k characters. However,

2-D barcode requires sophisticated readers making them more costly and unpopular in the retail industry.

(a) (b) (c) (d) (e) (f)

Figure 1.2: Two-dimensional barcodes, (a) 3-DI and (b) Array Tag, (c) PDF417, (d) Data Matrix, (e) MaxiCode and (f) Aztec Code

1.2 Limitations of Conventional Barcode Readers

Barcodes are used extensively in many areas especially in the retail industry. Although barcodes provide a fast and accurate method of data entry, the readers used for this purpose have some shortcomings. Laser scanners are far the most commonly used 1-D barcode reader. Laser scanners look at the pattern of dark and light bars and decode a barcode, returning the string contained in them. This string is then used to obtain additional information from a database. Several limitations of conventional scanners are;

a. Limited depth of field

Barcodes must be placed very close to the reader for a successful reading. This is true especially for pen type and laser readers.

b. Limited life span due to mechanical wear

Due to close contact between the reader and the barcode, the barcode reader is likely to have a limited life span due to mechanical wear. This is also due to the way the reader is handled by humans.

c. Barcodes must reside on flat surfaces

One of the biggest limitations is that most readers can only operate with barcodes that reside on flat surfaces. Barcodes placed on curved or irregular surfaces such as on cylinders are difficult to read.

d. Barcode alignment

Conventional barcode readers require that the barcodes are placed in a proper alignment prior to reading. Barcodes cannot be rotated or flipped. The success in reading a barcode depends greatly on how the barcode is aligned. In actual application environment, proper alignment of barcodes means human intervention, thus a fully automated system in not feasible.

e. Cost

Although there are variety of barcode readers available, models that do provide high-end features such as low error rate and high robustness, are often expensive.

f. Laser hazard

Because the eye focuses laser light just as it does other light, the chief danger in working with lasers is eye damage. Therefore, laser light should not be viewed either directly or reflected. Direct exposure to laser light should be avoided. Laser scanners present danger if accidentally pointed into the eye.

The application of vision in many areas is much sought after due to several advantages. Vision based barcode readers can be used when the object is far away or when human intervention is difficult or hazardous such as in the handling of radioactive materials. Vision systems can perform multiple things at the same time, without changing the hardware but just by modifying the software to suit a particular operation. In industries, vision is used to detect production defects, detect missing components and also to obtain barcodes. All of this is performed with one vision without the need for a dedicated hardware for every operation. Besides that, the sources of vision such as digital cameras are becoming more common and

economical. With the sudden growth in consumer based digital cameras (such as in mobile phones and Personal Digital Assistants (PDAs)), it becomes even clearer that vision will be available to the masses in the near future, thus there is a strong motivation to develop vision based applications.

1.3 Objectives

The main objective of this project is to develop a system comprising of a camera and software for the purpose of capturing 1-D barcodes and decoding them in real-time. Suitable image processing techniques must be implemented in the software to accommodate inaccuracies or environmental changes during the acquiring process. The project is also aimed at addressing the issues with conventional readers. Lastly, the objective of this project is to compare the performance and robustness of the final system with currently available vision based barcode reader technologies.

1.4 Scope of Project

The project is focused on developing a Windows based software using Microsoft Visual C++ 6 that will perform the image processing and decoding. The scope of the project will cover the following areas;

1. The program obtains images or frames from offline Windows Bitmap (BMP) files or in real-time from a camera or framegrabber that is interfaced to the system.
2. The program developed must be able to decode two 1-D symbologies, the UPC-A and EAN-13.
3. It is also the aim of the project that the program is able to decode barcodes in various alignments, on different surfaces and in various environment conditions.

4. Finally, the algorithms must be fast and efficient so that it can be applied in real-time applications. It is the target of the project that the final program is able to perform detection at a rate of 20 frames per second (FPS).

1.5 Project Outline

The project is organized into six chapters. The outline is as follows;

Chapter 1-Introduction
This chapter discusses the objectives and scope of the project and gives a general introduction to barcode technology.

Chapter 2-Review of Literature Studies
This chapter reviews the relevant literature and previous work regarding vision based barcode readers. In addition to that, the anatomy of EAN-13 and UPC-A symbologies are given.

Chapter 3-Theoritical Background
Chapter 3 elaborates on the principles behind good quality image acquisition and the factors that must be taken into consideration to obtain readable barcodes. This includes lens selection, determination of field of view, and depth of view.

Chapter 4- Algorithms & Implementation
All the preprocessing executed prior to detection is explained in this chapter. The algorithms to initiate barcode detection and decoding are also described and justified in this chapter.

Chapter 5-Result

The final results of this project are shown and discussed in this chapter.

Chapter 6-Conclusion

Chapter 6 consists of conclusion and suggestions for future improvement.

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